ERDC TN-DOER-C28
August 2002

Evaluation of Surface Runoff Water in a Freshwater Confined Disposal Facility—Effects of Vegetation

PURPOSE: The U.S. Army Engineer Research and Development Center, Vicksburg, MS, is conducting a series of laboratory and field studies to determine the effectiveness of the Simplified Laboratory Runoff Procedure (SLRP) for evaluating water quality of surface runoff from the upland placement of dredged material. The purpose of this technical note is to summarize the tests being conducted and to provide results from tests that have been completed at the Jones Island confined disposal facility (CDF) in Milwaukee, WI. The field portion of work at the Jones Island CDF began in June 2001 and was scheduled for completion in May 2002. Additional sites will be selected to include a CDF containing saltwater dredged material. Other technical notes will follow as tasks are completed.

BACKGROUND: Runoff is the water and associated suspended and dissolved materials released from island, nearshore, or upland CDFs during or after rainfall or other precipitation that results in a surface flow of water over exposed dredged material. The runoff pathway is of potential concern as soon as effluent from the dredging process is drained from the surface of the dredged material and the dredged material is exposed to air and the process of precipitation. Unlike the effluent pathway, the runoff pathway may continue to be of concern through the life of the CDF.

Before contaminated dredged material is placed in a CDF, impacts of the runoff discharge to receiving waters must be considered. The CDF runoff is defined in 33 CFR 323.2 (d) and 40 CFR 232.2 (e) of the Clean Water Act (CWA) as a dredged material discharge and is regulated as such under Section 404 of the CWA. Section 401 of the CWA requires that all Federal permits and licenses for discharges (including dredged material) into waters of the United States authorized pursuant to Section 404 must be certified as complying with applicable State water quality standards (WQS). Evaluation of runoff water quality is required to determine compliance with applicable numerical or narrative standards.

The protocol for evaluating the runoff pathway, described in the Decision-Making Framework (Lee et al. 1991), is being updated in the upcoming Upland Testing Manual (U.S. Army Corps of Engineers, in preparation) and will include the SLRP (Price and Skogerboe 2000). The evaluation follows a tiered approach in which the SLRP is conducted as a Tier III test to determine potential migration of contaminants in runoff water. The SLRP is basically a water extraction test on wet anaerobic dredged material to represent freshly placed dredged material and on dried and oxidized dredged material to represent aged dredged material in an upland condition. For metals, hydrogen peroxide is used to rapidly simulate the potential pH reduction caused by the presence and oxidation of iron sulfides to sulfuric acids and acidic iron (III) ions. If sufficient quantity of sulfides exists, sediment pH can be reduced to levels approaching pH 2 after drying occurs. As pH is lowered from above neutral to 6.5 and below, metals become more soluble. The SLRP is designed to provide an estimate of this potential, and results of the test may be compared to WQS. Where SLRP estimates exceedance or failure of WQS, management of runoff discharge may be necessary or additional tests may be conducted in Tier III to quantify results.

The Rainfall Simulator Lysimeter System (RSLS) is a physical model that applies simulated rainfall to generate runoff water from test sediment placed in a soil lysimeter. The ability of the RSLS to predict runoff water quality from the upland placement of dredged material was field verified under the Field Verification Program (Skogerboe et al. 1987; Folsom et al. 1988). The model has been applied to dredged material from a number of locations including Indiana Harbor, IL (Environmental Laboratory 1987), New Bedford Harbor, MA (Skogerboe, Price, and Brandon 1988), Oakland and Richmond Harbors, CA (Lee et al. 1992a, 1992b, 1993a, 1993b), and others. Contaminants have included heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, organotins, and dioxins. The RSLS requires eight to eleven 208-L (55-gal) drums of dredged material to conduct the runoff evaluation in the laboratory and requires a minimum of 6 months to allow for drying and aging of the material to simulate the long-term effects of oxidation on contaminant solubility. SLRP was developed to provide faster analytical results with significantly less sample volume to determine potential water quality implications.

Heavy rainfall on a CDF can dislodge sediment particles and contribute to high suspended solids concentrations in the resulting surface water. Runoff is not limited to rainfall alone but can result from melting of snow and frozen soil surfaces. The discharge of surface water from a CDF is dependent on a number of variables including storage capacity, structure design and management, vegetation coverage, and slope of dredged material surface. These variables are subject to consideration on a site-by-site basis and in some cases may be uncertain in the planning stage of a dredging project. Another variable in evaluating runoff water is suspended solids. The physical and chemical characteristics of the dredged material, intensity of rainfall, surface cover, and other factors will determine suspended solids in runoff water. If discharge of runoff from rainfall is necessary, adjusting retention times by raising weir boards to allow for settling can control suspended solids discharge. However, soluble contaminants may still be at elevated levels in the surface water column and must be addressed. Most freshwater CDFs will contain herbaceous and possible woody vegetation that may reduce the impact of rainfall on the dredged material surface by providing a canopy of living plant and plant detritus to cover the surface. The effect of plant cover on the generation of suspended solids in runoff water and resulting metals concentrations was evaluated at the Jones Island CDF in Milwaukee, WI, using the portable field RSLS. This technical note reports the results of that testing.

Site Description. The evaluation of water quality of fresh water is being conducted at the Jones Island CDF in Milwaukee, WI, on dredged material from the Milwaukee Harbor area. The facility was constructed in 1975 and accepts dredged material from Milwaukee and Port Washington Harbors. In recent years the annual disposal of dredged material from maintenance dredging has been reduced to approximately 19,000 m^3 from an annual input of up to 73,000 m^3. Remaining capacity of the 1.2-million-cubic-meter facility is approximately 300,000 m^3. The CDF is heavily vegetated (Figure 1) except for the ponded area (Figure 2), and most new placements of dredged material become vegetated within a growing season. The site was selected for four reasons: 1) ease of access, 2) a selection of contaminated dredged materials, 3) typical CDF characteristics, and 4) cooperative support from the Detroit District and the city of Milwaukee. The site has supported other dredged material research studies including bioremediation (Myers and Bowman 1999) and currently supports phytoreclamation research funded by the Dredging Operations and Environmental Research Program (DOER) and U.S. Environmental Protection Agency (EPA) contaminated sediment research programs.

Figure 1. The Jones Island CDF is heavily vegetated with mostly herbaceous vegetation

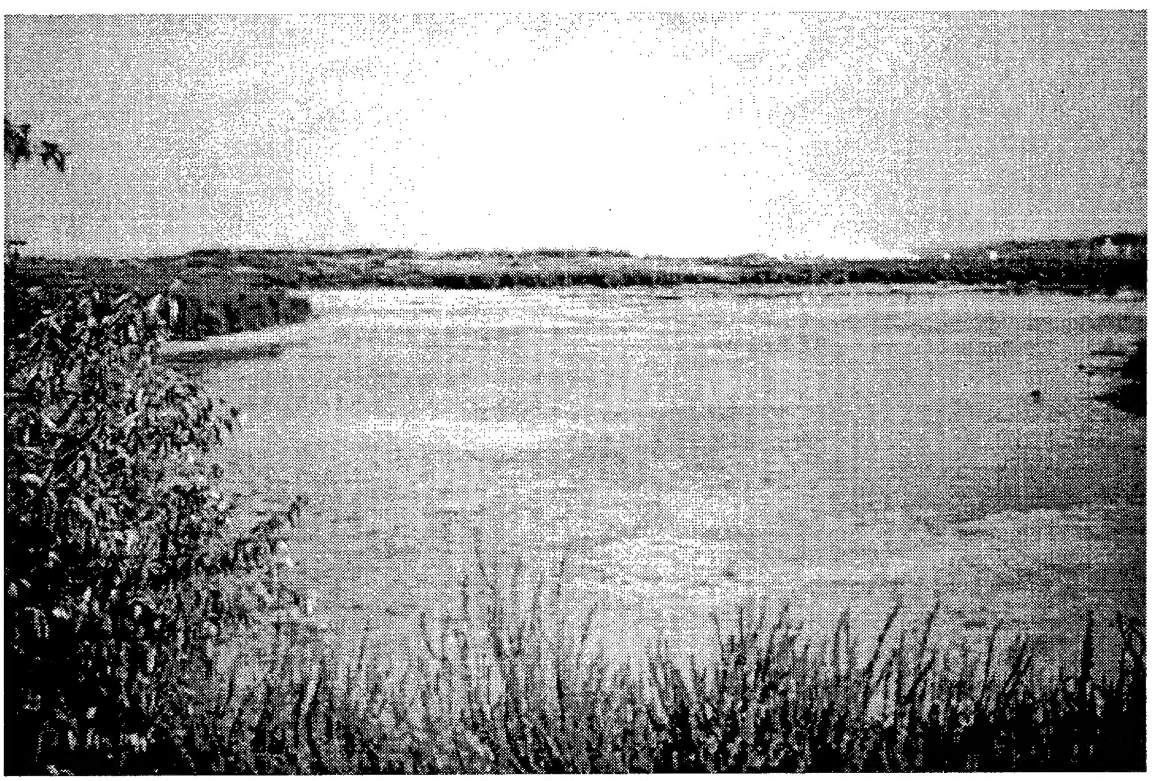

Figure 2. Runoff from upland portions of the CDF passes throught a ponded area prior to discharge through a sand filter weir

Table 1
Physical and Chemical Characteristics of Dredged Material in the Jones Island CDF

pH	7.8
Conductivity, mmhos/cm	2.88
Salinity, ppt	2.0
Sand, %	45.42
Silt, %	45.83
Clay, %	8.75
AS, mg/kg	5.95
Cd, mg/kg	3.13
Cr, mg/kg	693
Cu, mg/kg	106
Pb, mg/kg	196
Hg, mg/kg	0.46
Ni, mg/kg	26.3
Ag, mg/kg	1.96
Zn, mg/kg	387

Physical and chemical characteristics of the dredged material were determined in September 2000 as part of a DOER and EPA phytoremediation project (ARCADIS 2001). Characteristics of dredged material used in the Part I testing are shown in Table 1. Since the pH of the Milwaukee dredged material is above neutral, no significant elevation of soluble metals was expected. Because the southern end of the CDF is used as a snow dump for the city of Milwaukee, soluble salts near the snow dump are higher than normally expected in a freshwater dredged material due to runoff of road salt. Generally, soluble salts were below 1 mmhos cm^{-1} across the site based on soil cores collected in the summer of 2000 (ARCADIS 2001).

Project Objectives. The objectives at this project site were to determine the effectiveness of the SLRP for prediction of potential runoff water quality and to evaluate the effects of vegetative cover on suspended solids and soluble contaminants in runoff water. The fieldwork to carry out these objectives began in June of 2001 and was scheduled for completion in June of 2002. Both existing and newly placed dredged materials are being evaluated. Previously placed dredged material is being evaluated for effectiveness of SLRP in estimating metals in runoff from aged dredged material and effects of vegetation on suspended solids and soluble metals. Dredged material collected from the Kinnickinnic (KK) River was placed in a small demonstration cell and is being evaluated for metals, PAHs, PCBs, and pesticides. The results of this project will be reported in three parts. Part I will address the effects of surface cover on suspended solids and soluble metals in runoff from the existing dredged material. Part II will compare laboratory SLRP results from the anaerobic subsurface material to field rainfall simulator data from the aerobic surface. Part III will compare SLRP results on dredged material from the KK River to rainfall simulator data from the field demonstration plot, including metal and organic contaminants for freshly disposed and aged, oxidized dredged material.

METHODS AND MATERIALS: A field demonstration plot area was selected on a vegetated section of the Jones Island CDF. A 1.2-m-wide × 4.6-m-long plot was positioned on the area such that a slope of at least 2.5 cm of fall could be achieved along the length of the plot. Untreated 2.5-cm-thick × 10-cm-wide lumber was inserted into the dredged material surface to ensure that runoff would remain with the plot boundary and could be collected at the low end of the plot. A plexiglass, v-shaped trough was installed at the lower end of the plot to collect runoff using a water pump and Nalgene tubing. The portable rainfall simulator was positioned over the plot (Figure 3), and a rainfall event was conducted at a rate of 5.08 cm per hour for 30 minutes. Water used for the rainfall event was pumped directly from Lake Michigan off the dike of the CDF into two 2,400-L polyethylene supply tanks. During the rainfall event, samples of runoff were collected every minute for 15 minutes to determine runoff rates and every 5 minutes after that until 30 minutes had expired. The rain event ceased at 30 minutes, and runoff rates were measured every minute afterwards until the rate fell below 50 ml/sec. Samples were collected at 5, 15, and 25 minutes for chemical analysis

of metals. Samples were also collected at 5, 10, 15, 20, 25, and 30 minutes for determination of suspended solids concentrations. The surface of the dredged material was sampled for physical and chemical characterization prior to conducting rainfall events.

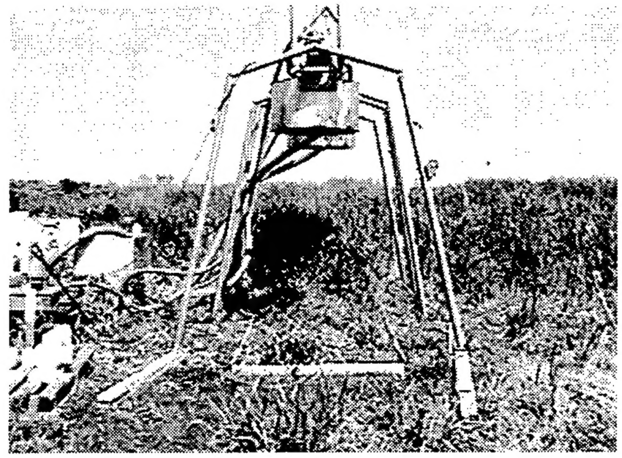

Figure 3. Rainfall simulation on the vegetated dredged material

After the rainfall simulation was completed on the vegetated plot, all aboveground vegetation was removed (Figure 4) and later dried and weighed to determine total dry weight biomass. Only the dead plant detritus of previous plant cover was left on the surface (Figure 5). The rainfall and sampling event was repeated exactly as before and then the detritus was carefully removed to expose the bare dredged material surface for the third rainfall event (Figure 6). Lakewater samples were collected from the rainfall simulator system at the beginning of the vegetated rainfall event and at the beginning of the bare soil rainfall event for chemical analysis of metals. Half of each sample for chemical analysis was filtered through a 0.45-µm membrane filter and then acidified to pH 2.0 with concentrated nitric acid. All runoff water samples were packed in an iced cooler and shipped overnight to the Environmental Chemistry Branch, Environmental Laboratory, Vicksburg, MS, U.S. Army Engineer Research and Development Center, for analysis following EPA methods (EPA 1993) for the determination of

Figure 4. Standing vegetation was harvested from the test plot

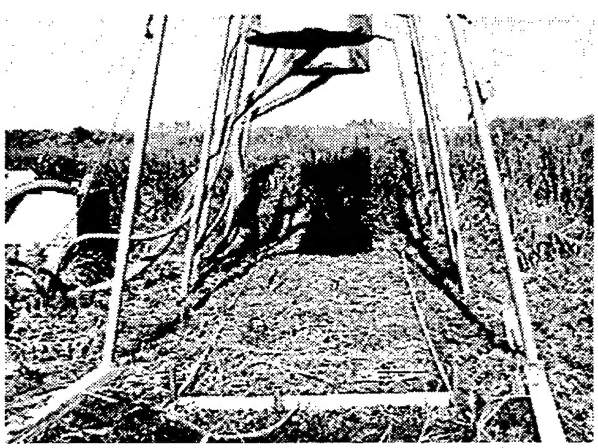

Figure 5. Rainfall simulation on surface plant detritus

Figure 6. Rainfall simulation on the bare dredged material

total and soluble metals. Suspended solids were determined by filtering 100 mL of runoff water through a pre-weighed 1.2-µm glass fiber filter according to Method 209 D (American Public Health Association 1981).

EFFECTS OF SURFACE COVER ON SUSPENDED SOLIDS IN RUNOFF: It is obvious that any cover over a soil surface will reduce the impact of rainfall droplets, which dislodge soil particles and result in erosion and increased suspended solids and associated contaminants in runoff water. Standing vegetation and dead plant material protect soil surfaces from the impact of rainfall, reducing suspended solids in runoff as shown in Figure 7. Standing vegetation had a dry weight biomass of 2,028 kg ha^{-1} and the underlying plant detritus had a dry weight biomass of 1,770 kg ha^{-1}. This resulted in an 84 percent reduction of suspended solids in runoff compared with that for exposed or bare dredged material. After the standing vegetation was removed leaving only the detritus, the suspended solids were still reduced by 74 percent compared with that for the bare surface. Suspended solids from the bare dredged material ranged from 1,380 to 3,338 mg L^{-1} with a mean of 2,128 mg L^{-1}. Suspended solids in runoff from the vegetated dredged material ranged from 166 to 480 mg L^{-1} with a mean of 339 mg L^{-1}. In each rainfall event, suspended solids were greatest in samples collected after the first 5 minutes of runoff. It should be noted that although some rather high suspended solids values were generated from the simulated rainfall event, actual discharges from the CDF at the weir would be much lower. As is the case with many CDFs, the Jones Island CDF has a freeboard capacity that permits ponding of runoff water. This allows for settling of suspended solids prior to discharge, and in some cases, freeboard capacity is sufficient to prevent discharge of runoff water.

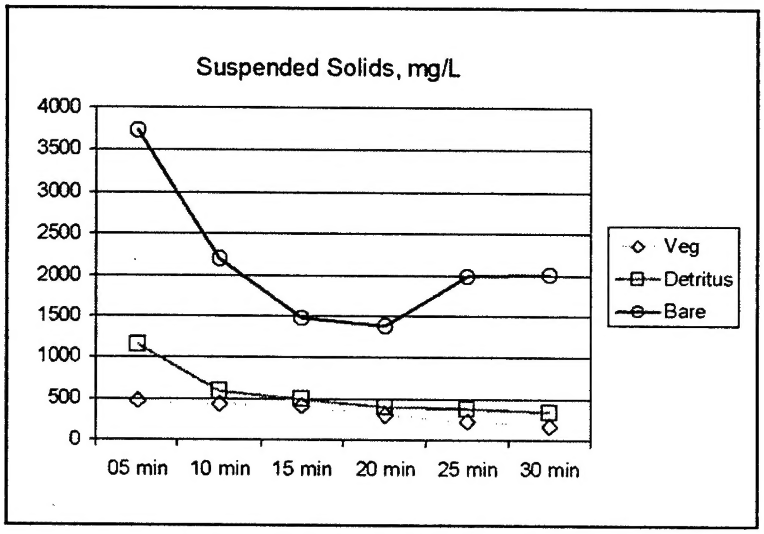

Figure 7. Effects of vegetation and plant detritus on suspended solids in runoff

The SLRP is conducted on dry, oxidized dredged material using suspended solids concentrations of 50, 500, and 5,000 mg L^{-1}. The results from the field runoff simulations verify that these concentrations do represent actual suspended solids concentrations possibly generated by rainfall under field conditions typical of many freshwater CDFs in the Great Lakes area. A suspended solids concentration of 5,000 mg L^{-1} in the SLRP procedure provides a conservative representation of rainfall runoff suspended solids generated from unvegetated, freshwater CDFs while 500 mg L^{-1} provides the same for vegetated CDFs.

EFFECTS OF SURFACE COVER ON METALS IN RUNOFF: Analytical results of total (unfiltered) contaminants are shown in Table 2 and are presented without blank (lake water) correction. Due to a mechanical problem during rainfall simulation on the vegetated surface, 5- and 15-minute samples were composited and are reported as such. The unfiltered lake water used to

Table 2
Total Concentrations,[1] μg L^{-1}, in Runoff Water During a 30-minute Rainfall Simulation

Time	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn
Bare									
5 min	59	38.8	873	662	3010	4.46	178	30	3760
15 min	25	15.2	370	334	1140	2.18	85	13	1690
25 min	18	10.8	253	227	822	1.45	60	9	1210
Detritus									
5 min	11	6.9	186	144	444	0.85	40	4	757
15 min	5	2.7	70	58	168	0.33	16	2	304
25 min	5	2.5	65	57	149	0.29	16	2	292
Vegetation									
5/15 min	5	2.7	72	63	161	0.4	21	2	287
25 min	3	1.6	41	36	190	0.2	12	1	181
Lake Water	<2	<0.2	6	6	4	<0.010	6	<1	36

[1] Not corrected for lake water contamination.

simulate the rainfall event had detectable concentrations of chromium, copper, lead, nickel, and zinc. Results demonstrate that the highest concentrations of contaminants occur in the first 5 minutes of rainfall, consistent with the occurrence of higher suspended solids in runoff.

Both dead and living plant cover had a substantial effect in reducing contaminants associated with suspended solids. With many CDFs in the Great Lakes area, most runoff enters a ponded area of the CDF and settling of suspended solids occurs over time. However, soluble contaminants may remain in the water column and be discharged when the water level of the pond exceeds height of the water control structure. However, simply reducing the suspended solids in precipitation runoff by managing a vegetative cover may not significantly reduce soluble contaminants. Soluble (filtered) metals in runoff from the bare and detritus- and vegetation-covered dredged material are shown in Table 3.

Filtered lake water had detectable concentrations of chromium, copper, nickel, and zinc. When these values are subtracted for chromium, nickel, and zinc, it is clear that the occurrence of these metals in the runoff water is a result of the lake water used in the rainfall simulation, not the dredged material rained upon. After correcting for blank contamination, all samples for chromium and all except 5-minute samples from the bare dredged material for nickel and zinc were not detectable (<1.0 and 10 μg L^{-1}, respectively). In addition, no detectable concentrations of silver were determined in the filtered runoff or lake water. Detectable concentrations of soluble arsenic, cadmium, copper, and lead did not differ significantly between rainfall events on bare or detritus- and vegetation-covered dredged material as did suspended solids associated contaminants.

When soluble metals are compared to suspended solids concentrations across all three dredged material conditions, concentrations do not significantly increase or decrease with suspended solids. Figures 8 through 11 compare total and soluble concentrations of arsenic, cadmium, copper, and

Table 3
Soluble Concentrations,[1] μg L^{-1}, in Runoff Water During a 30-minute Rainfall Simulation

Time	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn
					Bare				
5 min	3	0.3	1	15	1	<0.01	4	<1	81
15 min	2	0.3	1	10	<1	<0.01	3	<1	31
25 min	2	0.2	1	8	<1	<0.01	3	<1	26
					Detritus				
5 min	2	0.3	1	12	1	<0.01	3	<1	25
15 min	<2	0.2	1	8	<1	<0.01	3	<1	23
25 min	<2	0.2	1	6	<1	<0.01	3	<1	24
					Vegetation				
5/15 min	2	0.3	1	13	1	<0.01	3	<1	23
25 min	<2	0.2	<1	9	1	0.012	3	<1	18
Lake Water	<2	<0.2	4	5	<1	<0.01	3	<1	34
WQS[2]	150[3]	0.2	11[4]	9.0	2.5	0.77	52	3.4	120

[1] Not corrected for lake water contamination.
[2] EPA chronic toxicity criteria (corrected for lake water blank).
[3] Acute toxicity; no standard for chronic.
[4] As chromium VI.

lead, respectively, to suspended solids concentrations generated at 5, 15, and 25 minutes after runoff began for each plot condition. Multiple linear regression shows that while total metals increase linearly with suspended solids (r^2 = 0.94, 0.93, 0.94, and 0.93 for arsenic, cadmium, copper, and lead, respectively), soluble concentrations remain relatively unaffected by increased suspended solids (r^2 = 0.66, 0.10, 0.19, and 0.003 for arsenic, cadmium, copper, and lead, respectively).

A number of factors affect the soluble fraction of metals in runoff, the most important of which are pH of the dredged material and metal concentration in the dredged material. When dredged material becomes increasingly acidic (pH < 7.0) most metals become more soluble and less likely to precipitate out at higher soluble concentrations. The high pH of the Milwaukee dredged material limits dissolution of metals in the soil solution as well as in surface runoff. The pH of dredged material tested in the Jones Island CDF ranged from 7.4 to 8.2 with high levels of excess calcium (ARCADIS 2001). Solubility of most metals would be limited under these conditions. However, other freshwater dredged materials may exhibit different effects on metals solubility depending on pH, clay content, and other factors. Effects of pH are discussed in the following section.

The results suggest that suspended solids generation as a result of rainfall impact is not the primary driver for soluble metals in runoff. Increased disturbance of dredged material on the surface of a CDF certainly increases the potential mass of soil particles exposed to interaction with rainwater. Reduction of exposure through vegetative or other surface cover to minimize erosion may provide some benefit. Vegetation can be used as a source of treatment for removal of soluble metals; however, this requires a treatment zone of sufficient size outside the source of the contaminated runoff. Certain types of established vegetative cover could reduce runoff volumes by producing

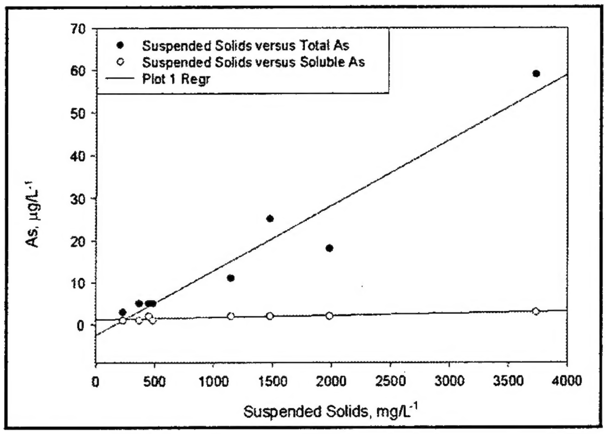

Figure 8. Total and soluble arsenic versus suspended solids

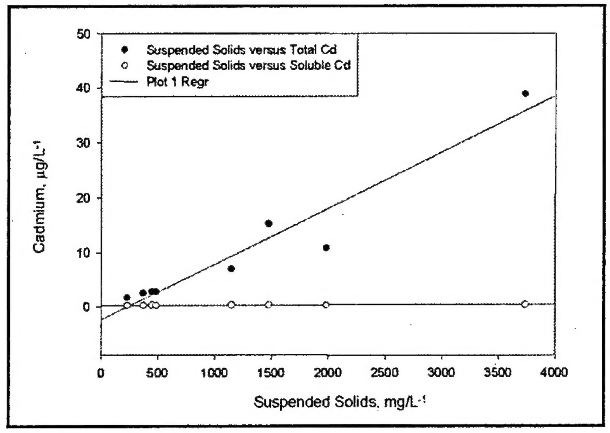

Figure 9. Total and soluble cadmium versus suspended solids

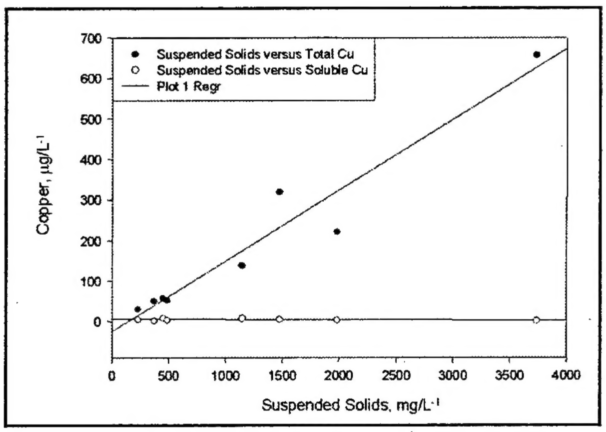

Figure 10. Total and soluble copper versus suspended solids

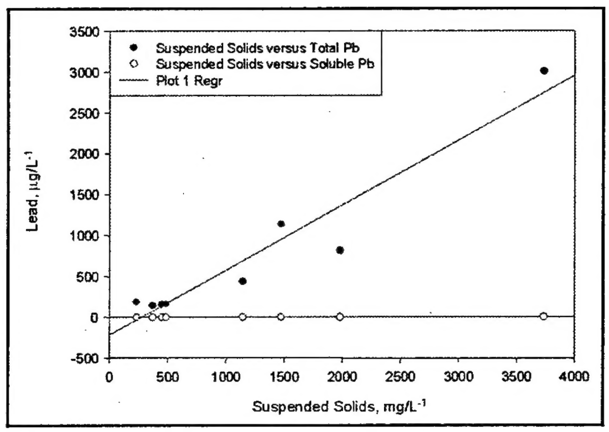

Figure 11. Total and soluble lead versus suspended solids

thick humic layers that act as sponges to absorb rainfall and may help to bind some metals. However, simply reducing the kinetic energy impacts of rainfall by providing a vegetative surface cover will not have a significant effect on soluble metals in the resulting runoff.

EFFECTS OF pH ON SOLUBLE METALS IN RUNOFF WATER: Previous studies on Indiana Harbor (Environmental Laboratory 1987), New Bedford Harbor (Skogerboe, Price, and Brandon 1988), and Blackrock Harbor (Folsom et al. 1988) dredged materials to predict runoff water quality were conducted. Physical and chemical characteristics of each (Table 4) show that while metal concentrations, particle size, and salinity differed, initial pH of each material was 7.5 to 7.6. Rainfall simulations were conducted on both fresh (mostly anaerobic and unconsolidated) and aged (dried, oxidized, and consolidated) conditions in laboratory lysimeters for Indiana Harbor and New Bedford Harbor and in the CDF for Blackrock Harbor. Under fresh conditions the pH of each material was above 7.5 and suspended solids ranged from 6,600 to 9,247 mg L^{-1}. Chemical analyses of both filtered and unfiltered runoff samples are shown in Figure 12 at pH 7.64, 7.60, and 7.54 for Indiana, Blackrock, and New Bedford, respectively. The mean ratio of soluble to total metals was 0.014, 0.005, 0.005, 0.176, and 0.26 for cadmium, chromium, copper, nickel, and zinc, respectively. After the dredged materials dried and consolidated, suspended solids in runoff were

Table 4
Physical and Chemical Characteristics of Dredged Material from Other Runoff Studies

	Indiana Harbor (Environmental Laboratory 1987)	New Bedford Harbor (Averett 1989)	Blackrock Harbor (Skogerboe et al. 1987)
pH	7.64	7.54	7.5
Sand, %	72.5	61	87
Silt, %	20	39	4
Clay, %	7.5	0	9
Cd, mg/kg	22.2	35.4	27.7
Cr, mg/kg	514	754	1650
Cu, mg/kg	266	1730	2520
Pb, mg/kg	933	2013	NA
Ni, mg/kg	120	122	180
Zn, mg/kg	3785	3020	1620

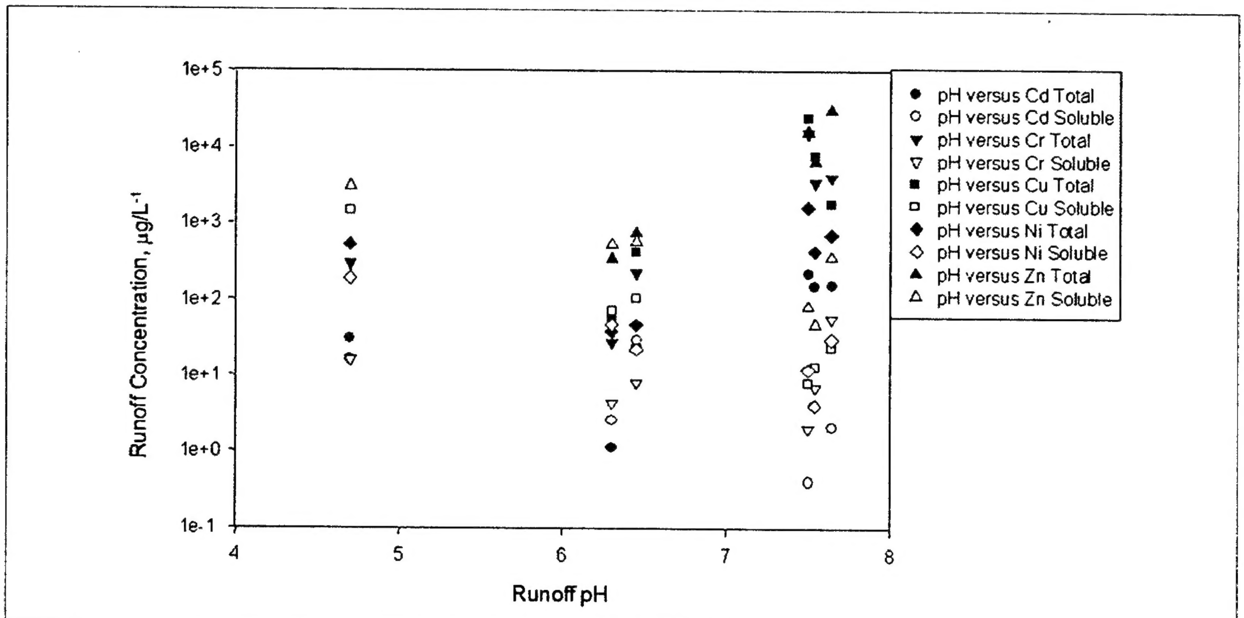

Figure 12. Total and soluble metals versus dredged material pH for Indiana, New Bedford, and Blackrock Harbor sediments

reduced to a range of 56 to 278 mg L^{-1}, which resulted in a reduction of total metals in runoff water. Sediment pH had been reduced to 6.30, 4.70, and 6.45 for Indiana, Blackrock, and New Bedford, respectively. However, with a decrease in pH to below 6.5 (Figure 12), the soluble to total ratio of cadmium, chromium, copper, nickel, and zinc increased to 1.35, 0.08, 0.86, 0.79, and 1.29, respectively, thus increasing the regulated fraction of metals that could potentially be released from a CDF in runoff discharge. In these cases, chemical treatment to increase the dredged material/runoff pH may be required to reduce soluble metals.

SUMMARY AND CONCLUSIONS: Rainfall simulations were conducted on dredged material in the Jones Island CDF to determine the effects of surface cover on runoff water quality. Vegetation and plant detritus significantly reduced suspended solids and total metal concentrations in runoff water but had little effect on soluble concentrations of metals. The results of this study indicate that although a dead or living vegetative cover may reduce the movement of contaminated dredged material in a CDF, the soluble fraction is mostly unaffected and will be a part of any water discharge from the CDF. Soil pH of the dredged material appears to be an important controlling factor for soluble metals in runoff water. Soil pH values of neutral or above are effective in substantially reducing soluble metals in runoff water. These results also indicate that the worst case assumption in the SLRP procedure (high suspended solids from bare dredged material) is suitable for predicting soluble metals from either bare or vegetated CDFs. Under vegetated conditions (lower suspended solids generation) soluble metals represented a higher percent of the total, although soluble concentrations did not change significantly between cover conditions. These results demonstrate that simply reducing suspended solids in runoff discharge may not reduce dissolved metals. However, soluble metals concentrations in runoff from the test plot in the Jones Island CDF were within EPA WQS for metals. The high pH and excess calcium concentrations in the Milwaukee dredged material kept soluble-to-total ratios of metals significantly less than those determined in the Indiana Harbor, New Bedford Harbor, and Blackrock Harbor studies where lower pH levels occurred. For dredged materials with the potential to produce lower pH levels, vegetation may not provide any reduction in soluble metals in runoff water, nor will physical separation of suspended solids from the water column by ponding. Additional controls or chemical treatments may be necessary to reduce the soluble concentration of metals generated by exposure of the dredged material to rainfall or other precipitation.

ADDITIONAL PROGRESS AND FUTURE PLANS: Analytical results of the SLRP on the anaerobic dredged material from the Jones Island CDF are complete, and will be published as a technical note. Rainfall simulations were conducted on the freshly placed KK sediment in June 2001. The sediment had dried significantly by August of 2001 and rainfall simulations on the dried, oxidized material were scheduled for the summer of 2002. The SLRP will also be conducted on the KK River sediment, and results will be compared with the field data and reported in a third technical note. This note will include both metals and organic contaminants.

Rainfall runoff evaluations on saltwater CDFs were initiated in April 2002. Plans are to publish laboratory rainfall simulations and SLRP results on New York Harbor sediment and begin field studies on Pearl Harbor dredged material for comparison with previously reported SLRP results.

ACKNOWLEDGMENTS: The author, Mr. Richard A. Price, gratefully acknowledges the contributions of Mr. Henry Banks, DynTel Corporation, for assistance in field and laboratory operations; Mr. David Bowman and Mr. Paul Baxter, U.S. Army Engineer District, Detroit, for providing logistical and contractor support for sediment collection and site preparation; and Drs. Michael R. Palermo, Paul R. Schroeder, and Charles R. Lee for providing thoughtful comment and review of this manuscript.

POINTS OF CONTACT: For additional information, contact Mr. Richard A. Price (601-634-3636, *Richard.A.Price@erdc.usace.army.mil*), the Contaminated Sediments Focus Area Manager, Dr. Michael R. Palermo (601-634-3753, *Michael.R.Palermo@erdc.usace.army.mil*), or the

Program Manager of the Dredging Operations and Environmental Research Program, Dr. Robert M. Engler (601-634-3624, *Robert.M.Engler@erdc.usace.army.mil*). This technical note should be cited as follows:

> Price, R. A. (2002). "Evaluation of surface runoff water in a freshwater confined disposal facility—Effects of vegetation," *DOER Technical Notes Collection* (ERDC TN-DOER-C28), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/dots/doer*

REFERENCES

American Public Health Association. (1981). *Standard methods for the examination of water and wastewater.* 15th ed., Washington, D C.

ARCADIS Geraghty and Miller. (2001). "Pre-demonstration characterization of dredged material, Jones Island Confined Disposal Facility, Milwaukee Harbor, Milwaukee, Wisconsin," Contract Report for U.S. Environmental Protection Agency and Science Applications International Corporation.

Averett, D. E. (1989). "New Bedford Harbor superfund project, Acushnet River Estuary engineering feasibility study of dredging and dredged material disposal alternatives; Report 3: Characterization and elutriate testing of Acushnet River Estuary sediment," Technical Report EL-88-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Environmental Laboratory. (1987). "Disposal alternatives for PCB-contaminated sediments from Indiana Harbor, Indiana; Vol I: Main report," Miscellaneous Paper EL-87-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., Skogerboe, J. G., Palermo, M. R., Simmers, J. W., Pranger, S. A., and Shafer, R. A. (1988). "Synthesis of the results of the Field Verification Program upland disposal alternative," Technical Report D-88-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Tatem, H. E., Brandon, D. L., Kay, S. H., Peddicord, R. K., Palermo, M. R., and Francingues, N. R., Jr. (1991). "General decisionmaking framework for management of dredged material, example application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Brandon, D. L., Tatem, H. E., Simmers, J. W., Skogerboe, J. G., Folsom, B. L., Jr., Price, R. A., Brannon, J. M., Brandon, D. L., Price, C. L., Averett, D. E., and Palermo, M. R. (1992a). "Evaluation of upland disposal of Oakland Harbor, California, sediment; Volume I: Turning basin sediments," Miscellaneous Paper EL-92-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Brandon, D. L., Tatem, H. E., Simmers, J. W., Skogerboe, J. G., Price, R. A., Brannon, J. M., Palermo, M. R., and Myers, T. E. (1992b). "Evaluation of upland disposal of Oakland Harbor, California, Sediment; Volume II: Inner and outer harbor sediments," Miscellaneous Paper EL-92-12, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Brandon, D. L., Tatem, H. E., Simmers, J. W., Skogerboe, J. G., Price, R. A., Brannon, J. M., Myers, T. E., and Palermo, M. R. (1993a). "Evaluation of upland disposal of John F. Baldwin Ship Channel sediment," Miscellaneous Paper EL-93-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Brandon, D. L., Tatem, H. E., Skogerboe, J. G., Brannon, J. M., Palermo, M. R., and Myers, T. E. (1993b). "Evaluation of upland disposal of Richmond Harbor, California, sediment from Santa Fe Channel," Miscellaneous Paper EL-93-18, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Myers, T. E., and Bowman, D. W. (1999). "Bioremediation of PAH-contaminated dredged material at the Jones Island CDF: Materials, equipment, and initial operations,"DOER Technical Notes Collection (TN DOER-C5), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Price, R. A., and Skogerboe, J. G. (2000). "Simplified Laboratory Runoff Procedure (SLRP): Procedure and application," Technical Note EEDP-02-29, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Price, R. A., Skogerboe, J. G., and Lee, C. R. (1998). "Predicting surface runoff water quality from upland disposal of dredged material," Technical Note EEDP-02-25, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Rhoades, J. D. (1982). "Soluble salts." *Methods of soil analysis*. C. A. Black, ed., Monograph No. 9, American Society of Agronomy, Madison, WI, 167-179.

Skogerboe, J. G., Lee, C. R., Price, R. A., Brandon, D. L., and Hollins, G. (1987). "Prediction of surface runoff water quality from Black Rock Harbor dredged material placed in an upland disposal site," Miscellaneous Paper D-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, J. G., Price, R. A., and Brandon, D. L. (1988). "New Bedford Harbor Superfund Project, Acushnet River Estuary engineering feasibility study of dredging and dredged material disposal alternatives; Report 4, Surface runoff quality evaluation for confined disposal," Technical Report EL-88-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers (USACE). "Evaluation of dredged material proposed for disposal at island, nearshore or upland confined disposal facilities - Testing manual" (in preparation), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

U.S. Environmental Protection Agency. (1993). "Test methods for evaluating solid waste; Physical/chemical methods," SW-846, Third Edition, Washington, DC.